Infrared Remote Sensing of Solar-induced Physiological Parameters of _Pinacea oleracea_ Canopy

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Abstract

Pinacea oleracea seeds obtained from a local farmer had been planted using standard procedures on a cultivated arable land in mid tropical summer period in the months of June and July, 2016 in Ede, semi urban western Nigeria. The growth pattern of _Pinacea oleracea_ has been studied via the infrared remote sensing of notable solar-induced physiological parameters of the canopy from germination to flowering stage. The physiological parameters observed were Canopy Reflectance at panchromatic wavelengths, Fluorescence, Fluorescence Intensity, Chlorophyll luminescence, leaf surface Moisture and temperatures. Measurements were taken 6 hourly every day for five days, at Germination, onset of Foliage and Flowering stages. Results showed that the spectral responses varied with cloud covers, time and sunshine hours of the day. Though slightly low at germination results also indicated that solar-induced canopy reflectance increased with the onset of foliage and became fairly sinusoidal at the flowering stage. Results further showed that Canopy Reflectance and fluorescence intensity as well as chlorophyll luminescence exhibited some degradation with time.

Key Words: Infrared Remote Sensing, physiological properties, _Pinacea oleracea_, Vegetation canopy

INTRODUCTION

Spinach, or "round leaf spinage", is a staple of the early American vegetable gardens. It is a quick-growing vegetable and easy to maintain. Spinach is in the classification system Family Amaranthaceae. _Pinacea oleracea_ is its official scientific classification name. Within Amaranthaceae there are about 102 genera and 1400 species worldwide.

Spinach is used raw in salads and cooked as a potherb. The leaves may also be canned or quick frozen. Spinach can be used as a source of vitamin A, B1, B2, niacin and calcium. The crop also has a hypo glycaemia effect that can be used in treating urinary calculi and lung inflammation. The seeds can be used as laxative and for treating breathing difficulties and liver inflammation.Spinach is an excellent source of vitamin K. Vitamin K is needed for blood clotting. Spinach is an excellent source of vitamin A in the form of beta-carotene. Spinach is a good source of foliate. Like most vegetables, spinach is low in calories, fat free, and a good source of fiber [1]. Any information on the growth pattern and how the health status of this highly nutritive plant can be monitored for early warning signs of stress and disease would be highly beneficial to consumers, growers, those in agric business and plant physiologists amongst others.

Plant physiological research has a fundamental role in advancing the frontier of knowledge that is essential for the better understanding of plants and their interactions with surrounding biophysical environments. It also plays a significant role in supporting other branches of science that deal with the practical application of knowledge and in the development of advanced technologies needed for improving biological systems in general and agricultural productivity in particular. Crop physiology deals with studying cultivated crops with the aim of increasing productivity by enhancing the inherent genetic capacities of crops as well as their adaptability to environments. To be effective in realizing such a goal, physiologists have to work within multidisciplinary research teams committed to a particular crop and/or to multi-cropping systems [2].

The spectral quality of light reflected from leaves, manifested in leaf color, and has long been relied upon as an indicator of plant stress. However, spectral characteristics of radiation reflected, transmitted, or absorbed by leaves can provide a more thorough understanding of physiological responses to growth conditions and plant adaptations to the environment. Investigation of canopy spectral characteristics has intensified greatly since the 1960s, along with the development of instrumentation and interest in the potential of remote sensing for stress detection. Largely as a result of interests in remote sensing, leaf reflectance has been studied more extensively than transmittance or absorbance responses to stress [3].
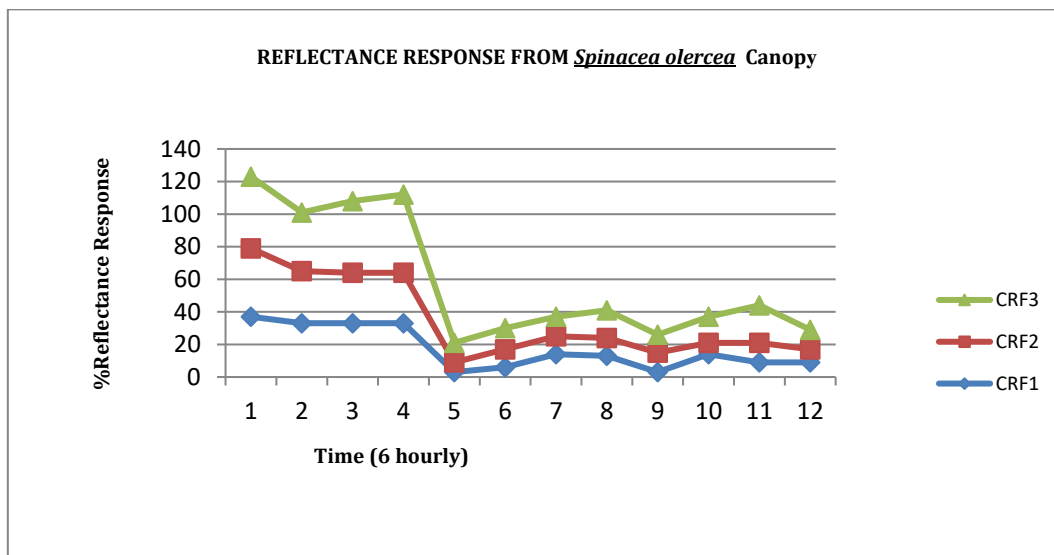
Figure 1: *Pinacea oleracea* Canopy

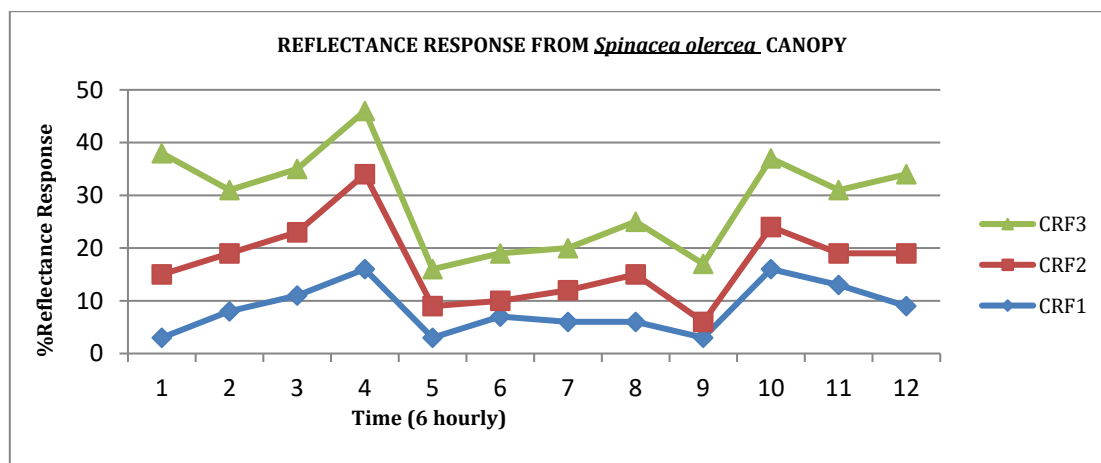Figure 2: Reflectance VS Time (6Hourly) at Germination

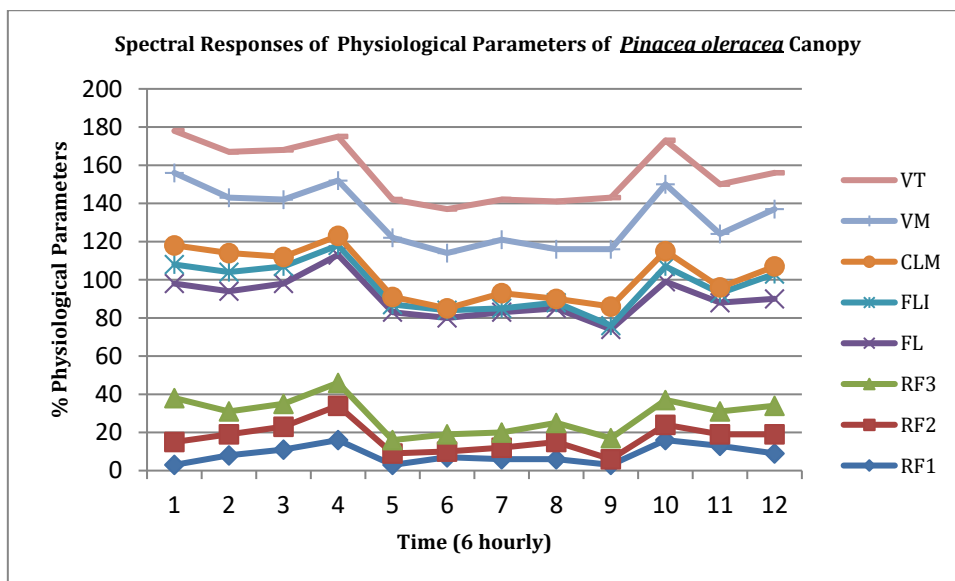Figure 3: Reflectance vs Time (6 hourly) at Germination

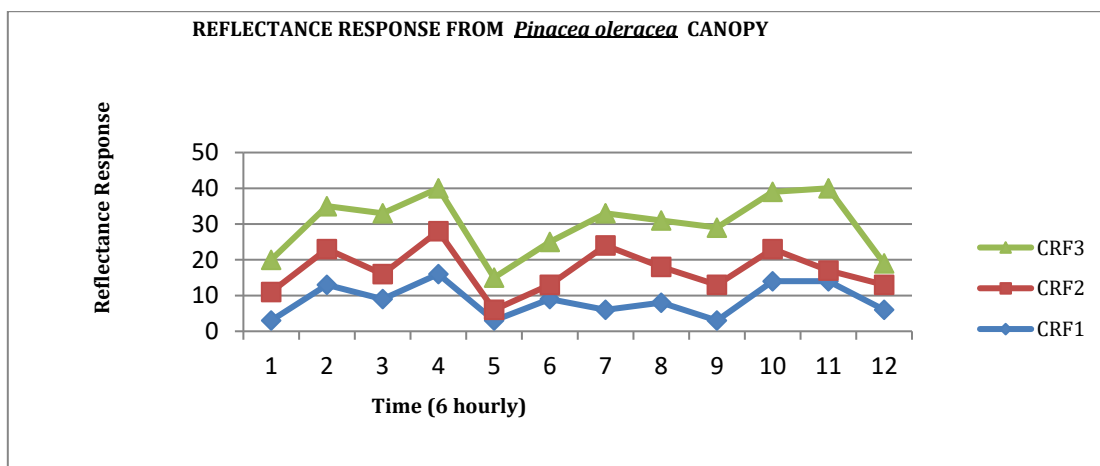Figure 4: Physiological Parameters vs Time (6 hourly)

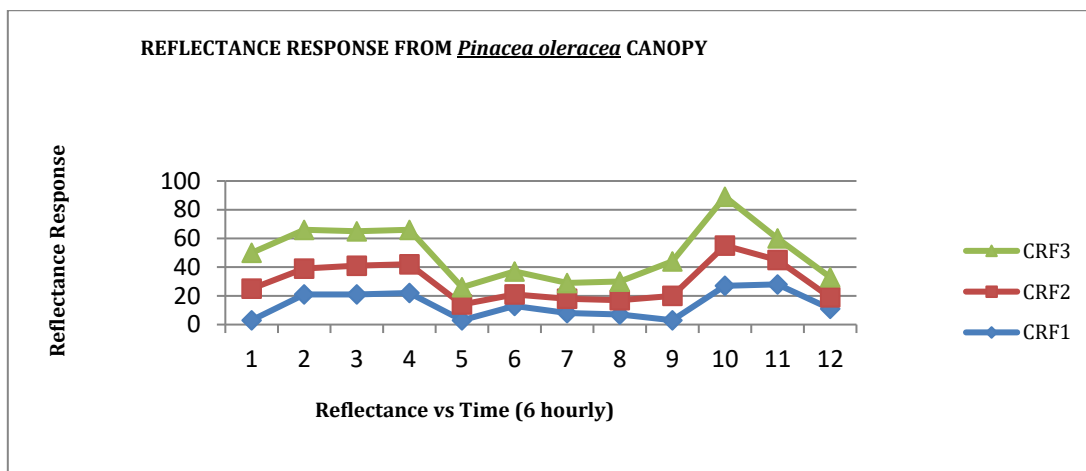Figure 5: Reflectance vs Time (6 hourly) at onset of Foliage

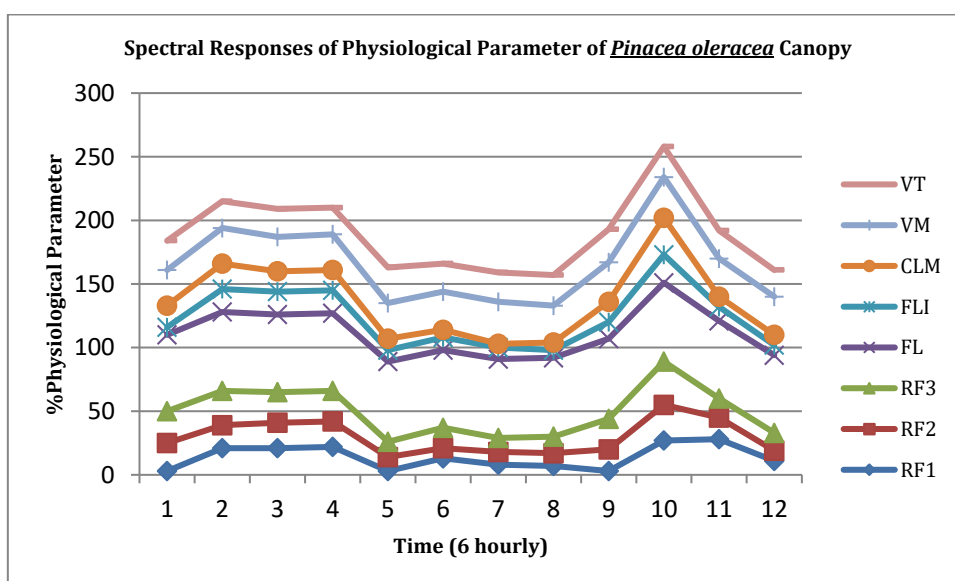Figure 6: Reflectance VS Time (6Hourly)

Figure 7: Physiological Parameters vs Time (6 hourly)
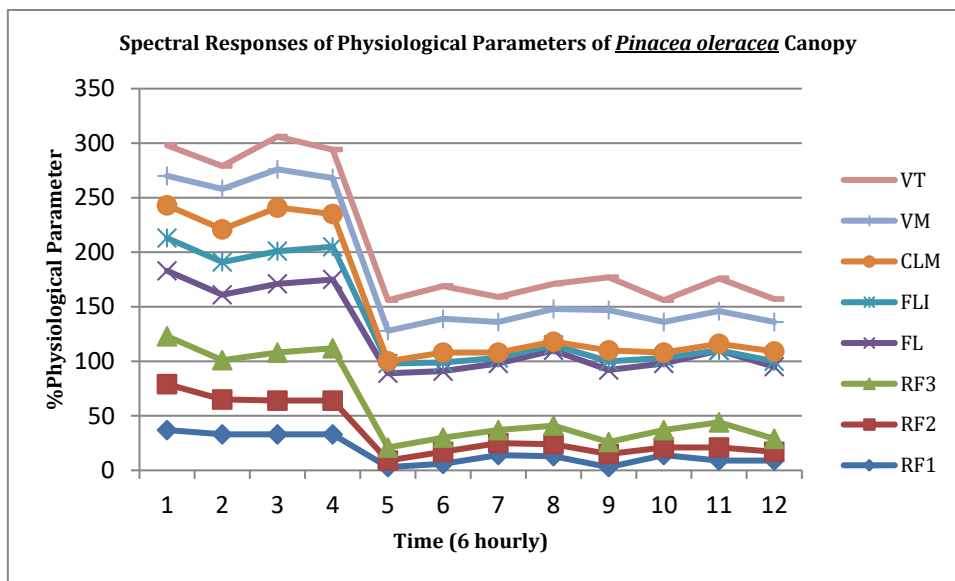
Figure 8: Physiological Parameters vs Time (6 hourly) at the onset of Foliage

Figure 9: Reflectance vs time (6hourly) at Flowering

Figure 10: Physiological Parameters vs Time (6 hourly)

Figure 11: Physiological Parameters vs Time (6 hourly)
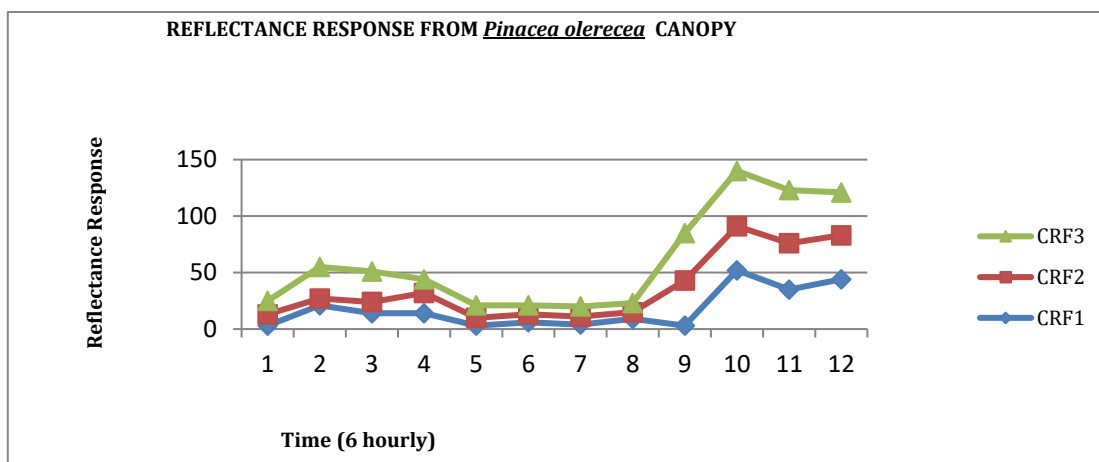
Figure 12: Physiological Parameters vs Time (6 hourly)
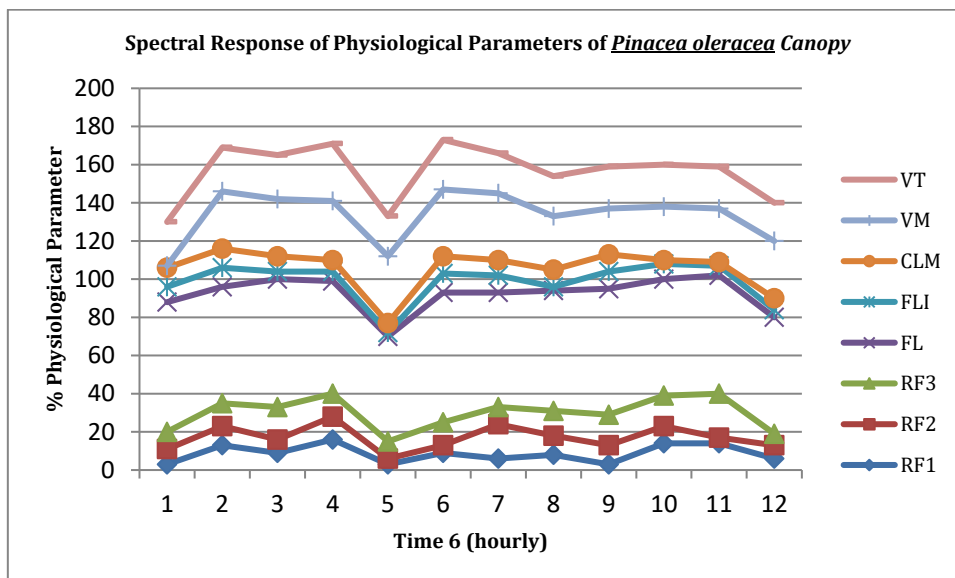

Figure 13: Physiological Parameters vs Time (6 hourly)
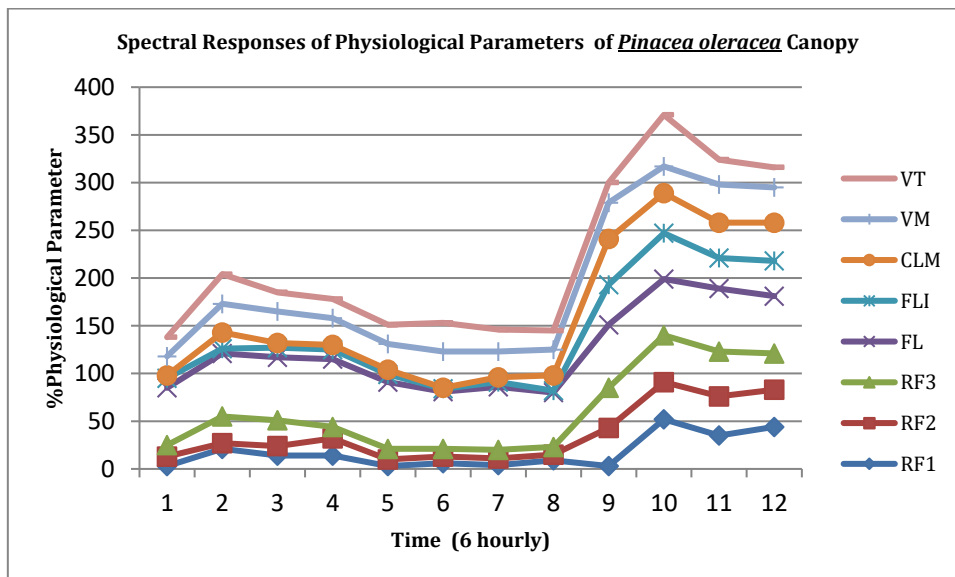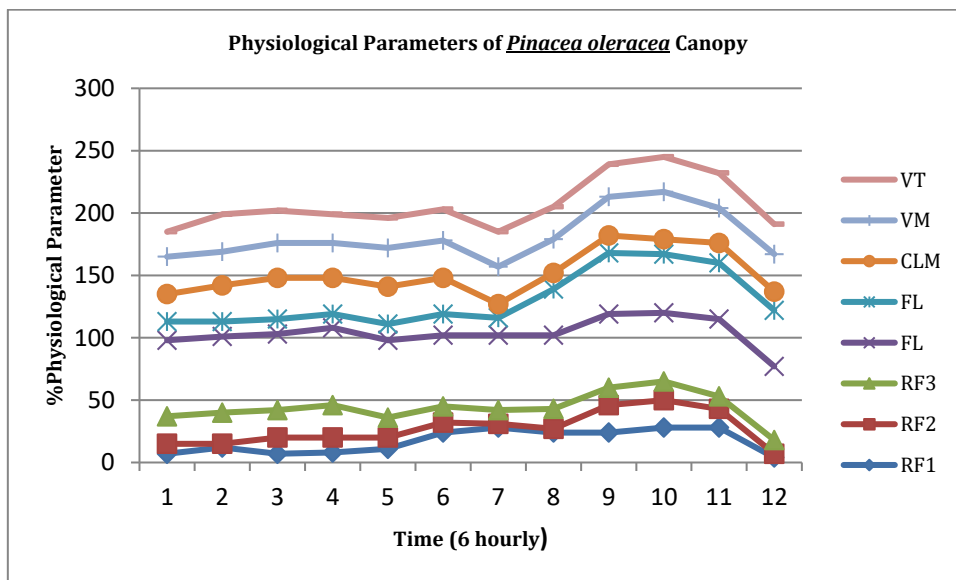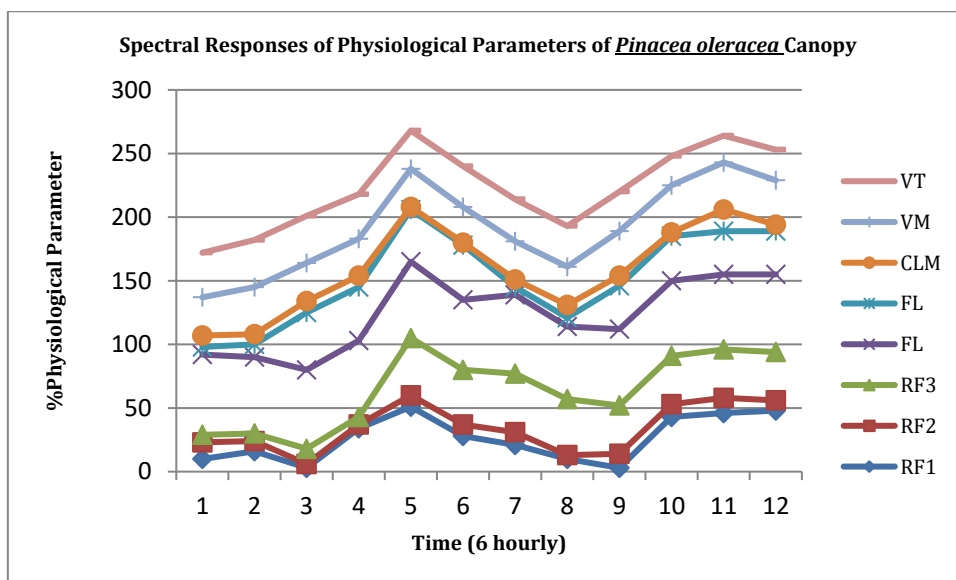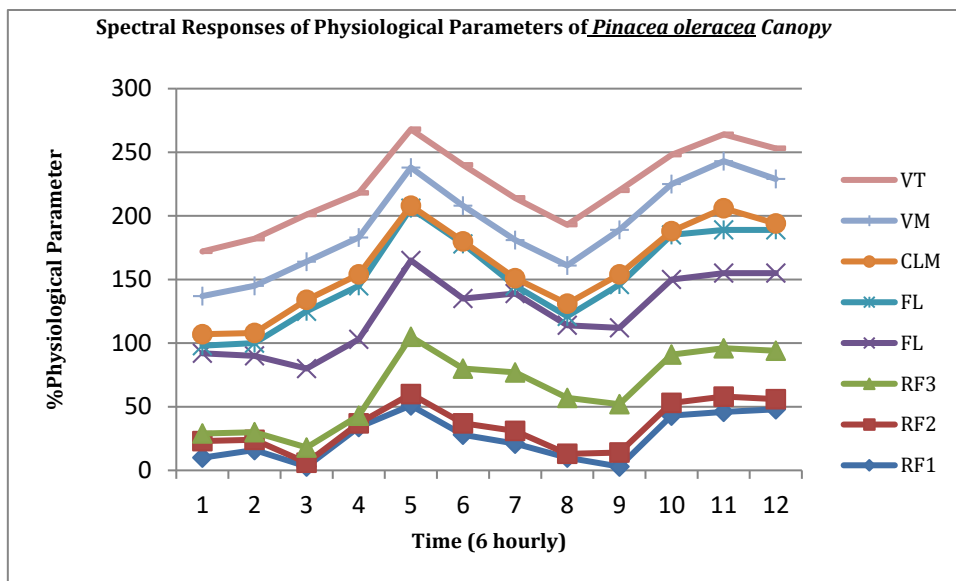
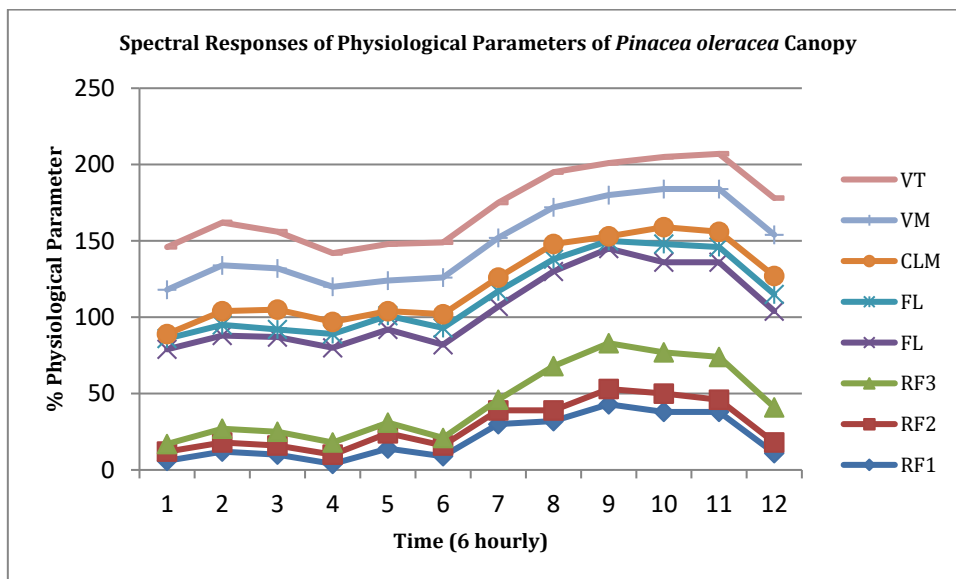Figure 14: Physiological Parameters vs Time (6 hourly)

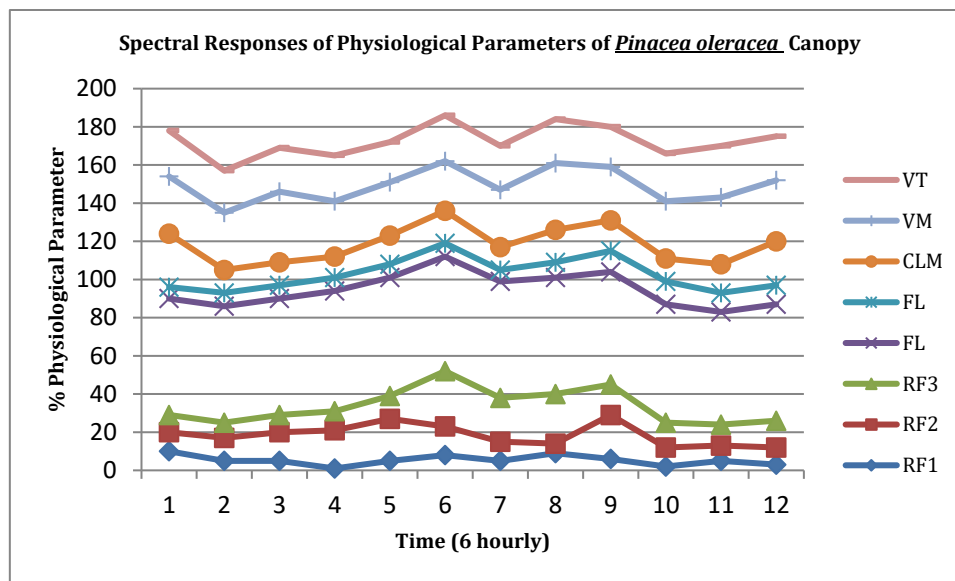Figure 15: Physiological Parameters vs Time (6 hourly)

Figure 16: Physiological Parameter vs at Flowering

The spectral behaviour of the leaf changes during senescence and in plants subjected to stress (e.g. disease, pest, etc.) by reflecting more Red lights and absorbing more NIR. Opposite behaviour is shown in healthy plants with high values of reflectance in the NIR region and low values in Red portion. Near-infrared (NIR) radiation is reflected from the structure of the spongy mesophyll tissue and cavities within the leaf. Therefore the percentage of radiation reflected from the leaf will be higher in the NIR than in the Green [4]. Canopy chlorophyll (Chl) content estimates using the colour chart has been verified using an independent estimate of canopy chlorophyll (Chl) from both satellite and multispectral reflectance data. Therefore, a leaf colour chart can also be utilized for quantifying both leaf and canopy chlorophyll (Chl) content. These methods utilize the absorption properties of chlorophyll (Chl) that use either the reflectance or transmittance of light by the leaf. Some newer sensors use the fluorescence properties of chlorophyll (Chl) to estimate its content [5]. The effectiveness of remote sensing of canopy temperature lies in the fact that the presence of water stress corresponds with a closure of stomata and a decrease in the transpiration rate, which is the main process responsible for cooling the plants, with a resulting increase in canopy temperature. However, crop temperature is sensitive to other variables, such as air temperature, relative humidity, wind speed, and incoming irradiance.

Thus, most of the mentioned studies have implemented methods to minimize the effect of these environmental variables [5]. Canopy water content provides a measure of the amount of water contained in the foliage canopy. Water content is an important quantity of vegetation because higher water content indicates healthier vegetation that is likely to grow faster and be more fire-resistant. Canopy water content use reflectance measurements in the near-infrared and shortwave infrared regions to take advantage of known absorption features of water and the penetration depth of light in the near-infrared region to make integrated measurements of total column water content [7]. This write up reports the use of infrared remote sensing of physiological parameters of *Pinacea oleracea* canopy using a new instrument [8], built for the purpose.

MATERIALS AND METHOD
The *Pinacea oleracea* seeds was gotten from the local market in Ede, semi urban western Nigeria and planted on sandy loamy soil on the farm using standard procedure in the months of June-July, 2016 in the mid tropical summer period. Spectral characteristics of the spinach leaves were measured from germination to foliage stage using the new instrument. Each spectral characteristics reading were taken at different wavelengths consecutively for number of days within the time interval of 8-

10am, 12-2pm and 4-6pm on each day and the readings were noted.

RESULTS AND DISCUSSION

The data was analyzed using the Microsoft Excel line charts and the observations were as shown on the accompanying Figures.

As expected, reflectance at the green wavelength is more intense by selective absorption. Absorption of solar radiation rich in blue wavelength is higher indicated by the low reflectance. Chlorophyll **a** absorption for photosynthesis action is intense while Chlorophyll **b** absorption at the red wavelength is less intense, at the germination stage. The absorption by both Chlorophyll **a** and **b** is less intense than at the germination stage as canopy reflectance appeared generally higher. Though, the reflectance varied with cloud movement and time of the day.

Reflectance generally appeared quite low or degraded until fourth day of the onset of Foliage shown on Figure 9, indicating high photosynthetic activity via high absorption of Chlorophyll **a** and **b** at blue and red wavelengths. Pronounce increase in reflectance on day 4 could be due to high solar insolation / intense sunshine hours.

It can be discussed that there is a favorable reflected radiation from spinach leaf canopy on each day with the time interval indicating high photosynthesis response of the plant when the green colored pattern is at peak at the flowering stage. The spectral responses appeared somewhat sinusoidal with time and sunshine hours of the day. The dips on the graphs indicated effects of cloud covers or overcast.

CONCLUSION

Pinacea oleracea seeds obtained from a local farmer had been planted using standard procedures on a cultivated arable land in mid tropical summer period in the months of June and July, 2016 in Ede, semi urban western Nigeria. The growth pattern of *Pinacea oleracea* has been studied via the infrared remote sensing of notable solar-induced physiological parameters of the canopy from germination to flowering stage. The physiological parameters observed were Canopy Reflectance at panchromatic wavelengths, Fluorescence, Fluorescence Intensity, Chlorophyll luminescence, leaf surface Moisture and temperatures. Measurements were taken 6 hourly every day for five days, at Germination, onset of Foliage and Flowering stages. Results showed that the spectral responses varied with cloud covers, time and sunshine hours of the day. Though slightly low at germination results also indicated that solar-induced canopy reflectance increased with the onset of foliage and became fairly sinusoidal at the flowering stage. Results further showed that Canopy Reflectance and fluorescence intensity as well as chlorophyll luminescence exhibited some degradation with time.

ACKNOWLEDGEMENT

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Appendix

Tables showing Raw data of Radiometric Measurements

Pinacea oleracea

RF1	RF2	RF3	RF4	FL	CLM	VM	VT
3	12	23	60	10	10	38	22
8	11	12	63	10	10	29	24
11	12	12	63	9	5	30	26
16	18	12	67	5	5	29	23
3	6	7	67	4	4	31	20
7	3	9	61	4	1	29	23
6	6	8	63	2	8	28	21
6	9	10	60	3	2	26	25
3	3	11	57	2	10	30	27
16	8	13	62	8	8	35	23
13	6	12	57	5	3	28	26
9	10	15	56	13	4	30	19

DAY 2

RF1	RF2	RF3	RF4	FL	CLM	VM	VT
3	8	9	68	8	10	1	23
13	10	12	61	10	10	30	23
9	7	17	67	4	8	30	23
16	12	12	59	5	6	31	30
3	3	9	55	2	5	35	21
9	4	12	68	10	9	35	26
6	18	9	60	9	8	35	21
8	10	13	63	2	9	28	21
3	10	16	66	9	9	24	22
14	9	16	61	8	2	28	22
14	3	23	62	5	2	28	22
6	7	6	61	4	6	30	20

DAY 3

RF1	RF2	RF3	RF4	FL	CLM	VM	VT
3	10	12	60	10	3	20	20
21	6	28	66	5	17	30	31
14	10	27	66	10	5	33	20
14	18	12	71	10	5	28	20
3	7	11	70	8	5	27	20
6	7	8	60	3	1	38	30
4	7	9	66	5	5	27	23
9	6	8	57	2	16	27	20
3	40	42	66	42	48	38	21
52	39	49	59	48	42	28	54
35	41	47	66	32	37	40	26
44	39	38	60	37	40	37	21

RF1	RF2	RF3	RF4	FL	CLM	VM	VT
33	32	36	60	30	30	37	21
33	31	44	63	30	40	35	30
33	31	48	63	30	30	33	26
3	6	12	68	9	2	28	28
6	11	13	61	8	9	31	30
14	11	12	61	5	5	28	23
13	11	17	69	5	3	30	23
3	12	11	66	8	10	37	30
14	7	16	61	5	5	28	20
9	12	23	66	0	6	30	30
9	8	12	66	5	9	27	21

DAY 5

RF1	RF2	RF3	RF4	FL	CLM	VM	VT
3	22	25	60	6	17	28	23
21	18	27	62	18	20	28	21
21	20	24	61	18	16	27	22
22	20	24	61	18	16	28	21
3	11	12	63	9	9	28	28
13	8	16	61	10	6	30	22
8	10	11	62	9	3	33	23
7	10	13	62	6	6	29	24
3	17	24	63	13	16	31	26
27	28	34	62	22	29	32	24
28	17	15	61	11	8	30	22
11	8	14	61	8	8	30	21